



REVIEW ARTICLE

COMPARISON ON COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF ZINC OXIDE, SILICON DIOXIDE AND MAGNESIUM OXIDE NANO-FLUID USING OIL AS A BASE FLUID IN HELICAL COIL HEAT EXCHANGER

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ABSTRACT

A brief evaluation of heat transfer through helical coil heat exchangers is present in this study. Improvement in heat transfer owed to helical coils has been stated by many scholars. Heat exchanger are significant engineering system with extensive variety of application including HVAC, power plants, heat recovery system, chemical processing, refrigeration and air conditioning system, food industries, nuclear reactors etc. Functioning towards the energy saving and to make short design for mechanical and chemical plants and plants, heat transfer plays a very important role in design of heat exchangers. We can improve the heat transfer rate by modifying the design by providing the helical tubes in place of straight tubes, and by using nano-fluids. Later authenticating the procedure of CFD analysis of a heat exchanger, the effect of seeing the actual fluid properties in its place of a constant value is established. Heat transfer characteristics inside a helical coil for various types of nano-fluids, they are. Zinc Oxide (ZnO), Silicon dioxide (SiO₂) and Magnesium Oxide (MgO) using oil as a base fluid are compared.

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INTRODUCTION

Through the growth of thermal engineering and industrial intensification, the need of efficient and compact heat transfer systems has been increased. In wide-ranging, the heat transfer enhancement methods are classified into two groups. Active method is the method which requires external power, whereas passive method does not require any direct external power. Helically coiled tube heat exchangers (HCTHE) as well as nano-fluids are regarded as passive heat transfer enhancement methods. The HCTHEs are widely used in many applications, such as electricity generation and nuclear industries, HVAC, piping systems, chemical reactors and refrigeration systems due to its high thermal efficiency and compactness (low volume to surface ratio). The curvature of helical coil which persuades secondary flow, in combining with more heat transfer area, contributes to the heat transfer enhancements of HCTHEs. Numerous studies have indicated that helically coiled tubes are superior to straight tubes when working in heat transfer applications. The centrifugal force induced due to the curvature of the tube results in the secondary flow development which enhances the heat transfer rate.

This phenomenon can be valuable, especially in the laminar flow regime (Vinita Sisodiya and Dr. Ankur Geete, 2016; Bahrehand and Abbassi, 2016). Heat transfer fluid is one of the serious factors as it disturbs the size and cost of heat exchanger systems. Conventional fluids like oil and water have partial heat transfer potentialities. For reduce cost and meet the increasing demand of industry and commerce we have to develop different types of fluids it is our top priority. By chance, the growths in nanotechnology make it possible to get higher efficiency and cost saving in heat transfer methods. Nanoparticles are occupied as the fresh group of materials which having potential applications in the heat transfer area. (Vinita Sisodiya and Dr. Ankur Geete, 2016; Bahrehand and Abbassi, 2016).

Nano Fluid

Nano fluid is nothing but it is a fluid particles which have less than even a micron (9-10 times) smaller in diameter and highly reactive and proficient material which can be used to increase feature like rate of reaction, thermal conductivity of any metal or material and they are that much reactive and strong (Kevin Kunnassery et al., 2017).

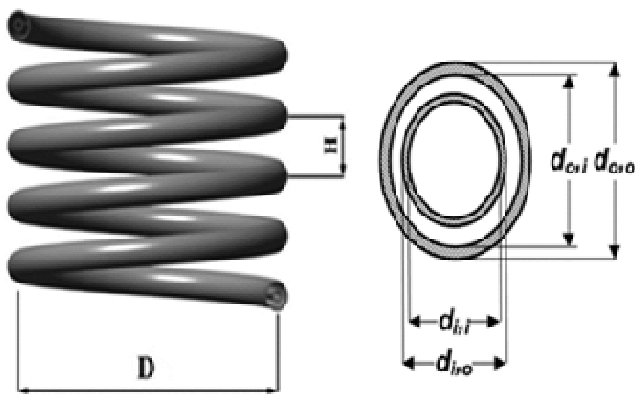


Figure 1.

http://thermalscienceapplication.asmedigitalcollection.asme.org/data/journals/jtsebv/930692/tsea_006_03_031001_f001.png

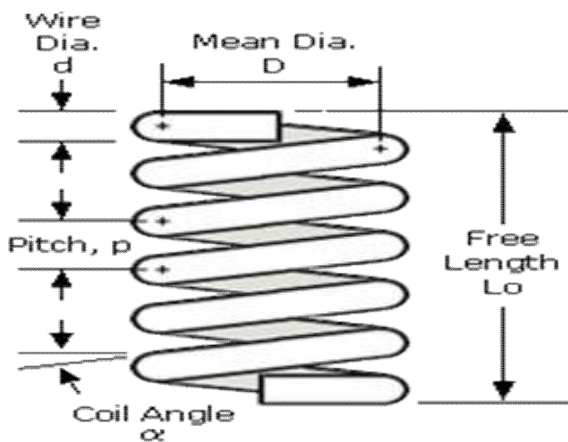


Figure 2.

(<http://engglearning.blogspot.in/2011/03/helical-spring.html>)

There are different types of Nano fluids basically:

- Al_2O_3 + Water
- CuO + Water
- ZnO + Water
- TiO_2 + Water
- TiN + Water
- MgO + Water
- SiO_2 + Water

The following benefits are expected when the nano fluid circulates the nano particles

- **Heat conduction is higher:** The thermal interface is directly available if the particles are better than 20 nm & if they carry 20% of their atoms on their surface. The nanoparticle is of μ size so there will be the advantage in the movement of particles and it increased the heat transfer because of micro convection of fluid. When the nano particles having large heat surface area then the large heat transfer is allowable. Dispersion of heat is increasing in the fluid at a faster rate because of large heat transfer. When there will be a rise in temperature then the thermal conductivity of Nano fluid increases

significantly (Sarit Kumar *et al.*, 2006; Amol Bari *et al.*, 2016).

- **Stability:** Nano fluids have nanoparticle of which is smaller in size (9-10 times smaller) or in μ size, so they are light in weight, that's why the chances of sedimentation are reduced. When sedimentation is dropping it will provide the stability in Nano fluid by settling the nano-particles (Sarit Kumar *et al.*, 2006; Amol Bari *et al.*, 2016).
- **Choking not occurs in Micro passage cooling:** For transferring of heat in heat exchanger the Nano fluid is a best option in overall and they can be perfect for micro passage uses where high heat loads are faced. A big area of heat transfer and directing fluids will occur by the mixture of micro path and Nano fluid and it cannot be managed with meso or micro-particles because they clog micro passages. Nano particles are smaller in size it is in μ which is very small to micro passage (Sarit Kumar *et al.*, 2006; Amol Bari *et al.*, 2016).
- **Probabilities of erosion reduced:** The momentum which is conveyed by a solid wall is minor because nanoparticles are very small. The probability of erosion of components is reducing when the momentum reduces and it occurs in pipelines, pumps and heat exchangers (Sarit Kumar *et al.*, 2006; Amol Bari *et al.*, 2016).
- **Pumping power is reducing:** Pumping power is increasing by a feature of ten. When the heat transfer of conventional fluid is increased by a feature of two. If there is a simple increase in fluid viscosity then the pumping power will be increased satisfactory. Thus, a large savings in pumping power can be attained. Thermal conductivity can also be increased by small volume fraction of particles (Sarit Kumar *et al.*, 2006; Amol Bari *et al.*, 2016).

The four distinctive features are listed below.

- **Improvement in thermal conductivity:** The nano particles are available in Nano fluid and nano particles have high thermal conductivity and by the properties of nano particles the thermal conductivity of nano fluid is also improved (Alpesh Mehta *et al.*, 2012).
- **Stability:** Nano fluids can be worked as a stabilized agent.
- **Newtonian behaviour and small absorption:** The nano particles in nano fluid maintaining the Newtonian behaviours of the fluid and nano particles are used in very small absorption that's why there is improvement in the thermal conductivity. The growth in viscosity was minimal; hence, pressure drop was increased to some amount.
- **Dependency in particles size:** Dissimilar the condition with micro slurries, the improvement of conductivity was found to be governed by not only on particle concentration but also on particle size. There is increased in improvement in conductivity when the particles size is reduced. All the above possibilities are compulsory for starting the research in Nano fluid with this probability that the Nano fluid will play a very important role for developing the next generation of technology. Nano fluid is stable and so much is expecting from Nano fluid with various application in future. It is essential to say that field in research of

Nano fluid is very important, with efforts from chemistry, mechanical and chemical engineering, physics, and material science (Sarit Kumar *et al.*, 2006).

Literature Review

Helical coil is very compact in structure and it possess high heat transfer coefficient that why helical coils heat exchangers are widely used. In literature it has been informed that heat transfer rate of helical coil is larger than straight tube.

Arvind Kumar Pathak *et al.* (2017) has done his study on the comparison of CFD analysis of Natural Fluid and Nano fluid in a helical coil heat exchanger. He has used water as a natural fluid and Titanium Oxide (TiO₂) and Zinc Oxide (ZnO) is used as a Nano fluid with base as water. He has fabricated a helical coil of aluminium and copper by bending 1000 mm of tube with 8 mm tube diameter, pitch 15 mm and coil diameter is 35 mm. He found that aluminium coil give more pressure drop on Zinc oxide Nano fluid as compared to other tubes and fluids.

Vijaykant Pandey and Dinesh Kumar Koli (2015) have done study on the effect of geometrical parameters on heat transfer in helical coil heat exchanger at three different mass flow rate 0.005, 0.02 and 0.05 kg/s. Helical coil was fabricated by bending 1000 mm length of aluminium tube having 6,8,10 mm tube diameter and each time coil diameter should be 40 mm and at same pitch 15 mm and at same length. The relation between pressure drop and mass flow rate has been obtained for three different curvature ratio 0.15, 0.2, 0.25 at three different mass flow rates. The result shows that by increasing the tube diameter 10 mm and at curvature ratio 0.25 at mass flow rate of 0.05 kg/s there is increase in pressure drop of about 12100 Pa (262.275 %) and Nusselt number also increases about 2.25% in comparison to tube diameter 6 and 8 mm and at mass flow rate 0.005 and 0.02 kg/s. This can increase heat transfer in helical coil heat exchangers. The increase in heat transfer are a consequences of curvature of the coil which induces centrifugal force to act on moving fluid resulting in development of secondary flow.

Abdul Hamid *et al.* (2015) has done work on pressure drop for Ethylene Glycol (EG) based Nano fluid. The Nano fluid is prepared by dilution technique of TiO₂ in based fluid of mixture water and EG in volume ratio of 60:40, at three volume concentrations of 0.5 %, 1.0 % and 1.5 %. The experiment was conducted under a flow loop with a horizontal tube test section at various values of flow rate for the range of Reynolds number less than 30,000. The experimental result of TiO₂Nano fluid pressure drop is compared with the Blasius equation for based fluid. It was observed that pressure drop increase with increasing of Nano fluid volume concentration and decrease with increasing of Nano fluid temperature insignificantly. He found that TiO₂ is not significantly increased compare to EG fluid. The working temperature of Nano fluid will reduce the pressure drop due to the decreasing in Nano fluid viscosity.

Fakoor *et al.* (2013) are studied the pressure drop characteristics of Nano fluid flow inside vertical helically coiled tubes are investigated experimentally for the laminar flow regime. The temperature of the tube wall is maintained constant at around 95 C to have isothermal boundary condition Experiments are implemented for fluid flow inside helically coiled tubes and a straight one. A wide range of various

variables is taken into account. Pitch to tube-diameter ratio ranges between 1.6 and 6.1 and coil-to-tube diameter ratio varies from 14.1 to 20.5. Heat transfer oil is used as the base fluid, and Multi-Walled Carbon Nano Tubes (MWCNTs) are utilized as the additive to provide the nano fluids. The working fluids are extremely temperature dependent, so rough correlations are proposed to predict their thermo-physical properties. Regarding the experimental data, utilization of helical coiled tubes instead of straight ones increases the pressure drop exponentially. Irrespective of the tube geometry in which the fluid flows, Nano fluid flows show higher rate of pressure drop compared to that of the base fluid flow.

Hemasunder Banka *et al.* (2016) have done an analytical investigation on the shell and tube heat exchanger using forced convective heat transfer to determine flow characteristics of nano fluids by varying volume fractions and mixed with water, the nano fluids are titanium carbide (TiC), titanium nitride (TiN) and ZnO Nano fluid and different volume concentrations (0.02, 0.04, 0.07 & 0.15%) flowing under turbulent flow conditions. CFD analysis is done on heat exchanger by applying the properties of nano fluid with different volume fractions to obtain temperature distribution, heat transfer coefficient and heat transfer rate. He found that heat transfer coefficient and heat transfer rates are increasing by increasing the volume fractions.

Srinivas *et al.* (2015) have done experimental study on heat transfer Enhancement using Copper Oxide (CuO)/Water Nano fluid in a Shell and Helical coil heat exchanger. Experiments have been carried out in a shell and helical coil heat exchanger at various concentrations of CuO nanoparticles in water (0.3, 0.6, 1, 1.5 & 2%), speed (500, 1000 and 1500rpm) and shell side fluid (heating medium) temperatures (40, 45 & 50°C). Water has been used as coil side fluid. He found that the heat transfer rate increases with increase in concentration of CuO/water Nano fluid. This can be attributed to increased thermal conductivity of base fluid due to the addition of nano particles.

Balchandaran (2015) have done experimental study and CFD simulation of helical coil heat exchanger using Solid works Flow Simulation using water as fluid. The fluid used for both coil and tube side is water. The flow rate of both fluids is maintained below as laminar and the flow rate of cold fluid is kept constant while that of hot fluid is changed. The readings during experimental study are taken once steady state has reached. The performance parameters pertaining to heat exchanger such as effectiveness, overall heat transfer coefficient, velocity contours, temperature contours etc. have been reported. Based on the results, it is inferred that the heat transfer rates and other thermal properties of the helical coil heat exchanger are comparatively higher than that of a straight tube heat exchanger.

Vinita Sisodiya and Ankur Geete (2016) study on the use of Helical coil heat exchangers (HCHEs) with (Aluminium Oxide) Al₂O₃ -Water phase change material to understand if HCHEs can yield greater rates of heat transfer. An analytical study was conducted using a counter flow HCHE consisting of 8 helical coils. Two analysis was conducted, one where water was used as heat transfer fluid (HTF) on the coil and shell sides, respectively; while the second one made use of different Volume fractions of Al₂O₃ and water on the coil and shell sides, respectively. The NTU effectiveness relationship of the

HCHE when Al_2O_3 fluid is used approaches that of a heat exchanger with a heat capacity ratio of zero. The heat transfer results have shown that when using an Al_2O_3 , an increase in heat transfer rate can be obtained when compared to heat transfer results obtained using straight heat transfer sections. It has been concluded that the increased specific heat of the Al_2O_3 as well as the fluid dynamics in helical coil pipes are the main contributors to the increased heat transfer.

Shiva Kumar and Vasudev Karanth (2013) have worked on both straight tube and helical tube heat exchanger. He has compared CFD results with the results obtained by the simulation of straight tubular heat exchanger of the same length under identical operating conditions. Results indicated that helical heat exchangers showed 11% increase in the heat transfer rate over the straight tube. Simulation results also showed 10% increase in nusselt number for the helical coils whereas pressure drop in case of helical coils is higher when compared to the straight tube.

Problem Formulation

In the literature survey we found that so much work had been done to increase the heat transfer rate in heat exchanger. But there is no work has been done on heat transfer rate of comparing the Manganese oxide (MgO) Nano fluid and Silicon dioxide (SiO_2) Nano fluid with oil as its base. In my work I am trying to showing the comparison of Nano fluid for the given helical coil heat exchanger keeping in mind that Nano fluid should produce maximum heat transfer rate with minimum power consumption. Because some times in the process of improving the heat transfer coefficient we consume more power without knowing the economic cost. Consider the helical coil heat exchanger of PCD 50 mm of length 1000 mm the pitch of the coil is 15 mm, the coil diameter is 8 mm & the material of coil is Copper & Aluminium. In my research I am using MgO and SiO_2 as a Nano fluid with oil as its base.

Conclusion

The different boundary conditions are taken for helical coil heat exchanger for the numerical simulations. The numerical study considers the effect of Nano fluid such as Manganese Oxide (MgO) and Silicon Dioxide (SiO_2) as oil as its base fluid on the flow and heat transfer characteristics of tube. The thermal properties of fluid are lesser as compared to Nano fluid. Nano fluids have Nano particles of solid materials which increase the thermal properties of Nano fluid also because of vortex flow the pressure drop will be increased. In all above literatures we found that normally the Nano fluid is used as water as its base for analysis of helical coil. We made a helical coil of 50 mm PCD and 8 mm tube diameter of length 1000 mm and the Nano fluid with oil as its base fluid is flow inside the tube. Nano fluid which has high thermal conductivity or specific heat that will give high pressure drop.

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